Mulch Based Agriculture

Green Manure Cover Crops and No Till Farming

by

William Scale

Alan and Anne Beckett Award

Acknowledgements

Without the support of a number of people this report would not have been possible, and I would not have had the opportunity to study one of the most exciting and challenging areas of crop production, a system which is likely to increase immensely in significance in the next 50 years.

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Introduction

Picture the scene for the moment. An earthquake hits a city. Many homes and buildings are destroyed, survival for humans is difficult.

People are trying to rebuild their communities after the disaster has torn down the walls of houses, damaged the streets and transportation networks, it will have destroyed water lines and other utilities, access to food is limited. Life would be tough. Some people would get sick, some would die.

Aside from the immediate tragedy, societies would take a long time to rebuild.

But this earthquake scenario happens every time we plough and till the soil. Complex communities of soil life are disrupted and destroyed. Worms are chopped, microbes exposed to the ultra violet sunlight, previous aeration and drainage channels are destroyed.

Such damage and losses may have been a price to pay before the advent of the concept of Sustainable Agriculture and current worldwide population pressure, but is it acceptable for the future?

The concept of needing to till fresh soil for crop production has long been in farmers' minds. Mentioned in the Bible the plough has long been held up as a symbol of successful and sustainable agriculture – and to a degree it has succeeded. But times have changed, technologies and science have developed in such a way that we are now able to understand that some of our traditional methods may not equip us for a sustainable future and they are in fact, extremely damaging.

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The inspiration for this trip has its roots in a trip I made in India as a wide-eyed backpacker half a decade ago.

Whilst travelling around the subcontinent I picked up a book written by a Japanese farmer Masanobu Fukuoka called "THE ONE STRAW REVOLUTION". Fifty years ago Fukuoka, a former agricultural scientist specialising in plant diseases, began questioning the basic principles around which modern farming is organized. He advocated a system of *natural farming*. Its central tenets were that soil cultivation was immensely damaging and that good farming should imitate nature or natural processes. Chief amongst this is the idea that soil naturally clothes itself with a mat of dead or decaying vegetable matter – herein known as a **mulch**, and that crop production and the environment would benefit hugely from following this principle.

The book had a profound effect on me, not because I wished to blindly follow an agricultural guru (I was in India at the time after all!) but because it forced me to challenge my preconceptions about what was the best way to farm for the future and that actually, maybe the Western tillage tradition didn't necessarily fit the mould. Certainly I knew that my annual cropping system of ploughing, tilling and drilling didn't leave me any profit at all in a lean year – thank goodness for the subsidy! Furthermore it seemed to me that minimum tillage was unlikely to provide the cost and environmental savings I wanted to make.

Fukuoka's model has never been taken up commercially and is likely to be limited on all but small scale farms, not least because he did not like using fertilisers or agrochemicals to help him, and therefore it was very labour intensive. My view is that whilst Fukuoka had valuable points about fertilisers weakening plant strength and pesticides contributing to some environmental problems, the benefits of adherence to "organic" principles are outweighed by gains from judicious use of external artificial inputs.

Unbeknown to me at the time of reading the book, a revolution was, and continues to take place in South America and latterly parts of the USA. And frustratingly it has largely been ignored by subsidised Western European farmers.

I went to visit pioneer farmers, researchers, extension staff and mavericks in Paraguay, Chile and the USA who have been perfecting systems of growing annual crops with minimum movement of the soil. Often viewed with a mixture of scepticism and suspicion by their peers, the people I had the privilege to meet are now finding that science and fellow farmers are at last catching up with them….

PART A

What am I talking about?

A *mulch* is a layer of vegetation, dead, decaying or living, that acts as a protective cover over the soil. This has many advantages for the soil and if you look around in woodlands, grasslands or anywhere where nature is left to its own devices you will find that nature is *mulching* itself. Always feeding, covering and protecting itself from the elements – and in agricultural situations we interpret these as weeds, green manures, crop and animal residues or grass leys.

There is no doubt *mulch* is a bit of an amusing word especially if you keep repeating the virtues of the mulch in public! I have found you will attract a raised eyebrow from your peers when using it!

Nevertheless this little appreciated biological process could be of great importance for future agricultural production and the politics of climate change.

Why the mulch?

There are many millions of hectares of direct drill farming in the USA, Canada and Australia. These tend to be simplified modern farming systems which save on soil erosion but do not necessarily make the best use of agro-ecological principles for nutrient, pest and weed management.

Developments in South America and parts of the USA have been more exciting, they have adopted the principles of not tilling the soil and developed a more holistic approach, which allows great efficiencies. They have recognised that crop covers have a vital role in improving soil condition and fertility and they have looked in more detail at ways the plant cover interacts to provide a tilth in which seeds germinate, without any application of applied horsepower.

Soil tillage - "But we've always done it …"

Well we haven't actually! And there are serious reasons to doubt whether it is necessary for the future. The first prehistoric farmers of central Europe – the Linearbandkeramik culture that arose slightly before 5000 BC - were initially confined to soils using hand held digging sticks. Only 1000 years later with the invention of the Ox drawn plough were farmers able to extend cultivation to a much wider range of heavier soils and tough sods. These practices have led to an agriculture yielding more food than before, and the plough enabled one person to cultivate a larger area of ground than they would have by hand.

Similarly in the New World the Aztecs and the Incas used planting sticks called dibblers, as did native North Americans until the advent of the European animal drawn plough. Before this of course they had no draught animals to till – Camelids such as alpacas don't make obedient draft animals! Another interesting difference is that New World farmers as a result of not ploughing, would plant seeds individually not scattered on handfuls of bare soil. Therefore their fields were less of a monoculture and contained more variety of plants.

In Papua New Guinea people have been living sustainably for 46,000 years and have practiced agriculture for 7000 years. They always mulched the soil of their steep sloped heavily with as much vegetative organic matter as possible to preserve soil fertility and protect it from erosion. To European colonisers, New Guinean highlanders appeared primitive, but in actual fact appearances proved deceptive because their farming methods were sophisticated, so much so that in some cases we still don't understand why some of the well intentioned European farming innovations failed there.

So the context is that the plough has in the past brought us undoubted riches. More grains than otherwise possible, especially if for example you consider the mass ploughing up in the post war years in the UK.

Ploughing has been relatively efficient in weed control. For example the modern steel mouldboard plough helped avoid famine and death at the end of the 18th century, since it was the only tool that could effectively control couch grass, a weed that had spread all over Europe and could not be controlled with conventional tools of the time.

So the plough and tillage have become the most frequently used symbols of agriculture worldwide. The tool that the colonial powers took to America, Asia and Africa became important in developing newly cultivated lands. It has taken many decades to discover that the same tool that brought food and wealth to Europe, would bring soil erosion and degradation to more fragile environments. The plough that has brought temporary control of weeds has come at a cost, and there is little in the way of scientific evidence that ploughing is beneficial to soils, yields or to the economics of modern farming.

Today the forces of change are pushing Western Europe to look again at excessive soil tillage and assess whether it has a place within sustainable agriculture, and whether we can afford the soil losses the plough generates? And what is it we can now learn from those countries to whom we exported the plough technology originally?

If it ain't broke? – The Problems of Soil Tillage.

The expansion of UK tillage based activities since the 1940's have increased the exposure of soil to the elements. Soil tillage has long been viewed as acceptable, or natural even. The more science tells us about the soil the more that we are discovering that the ground beneath our feet hosts a myriad interdependent organisms of which we knew nothing 30 or perhaps even 10 years ago. If I had a crystal ball and was respected enough for people to want to listen I would suggest that science will prove to us in the next thirty years that much of what we now view as the correct traditional way to grow crops is not so suitable in the future.

Soil tillage confronts us with a number of issues which we are now struggling to manage sustainably – and we now need to consider seriously the concept of sustainability (and therefore Sustainable Agriculture) for it is written into our European and devolved constitutions. It is surely only responsible that we try and find a way not just to window dress existing agricultural practices but also to think more philosophically about the way we choose to produce?

For example soil tillage has implications for the following and the report will deal with each aspect:

- Soil Erosion
- Soil Quality
- Soil Structure
- Soil Fertility
- Soil Carbon

Soil Erosion

Erosion in agriculture results from any of several changes that remove the plant cover normally protecting the soil:

- Overgrazing
- Noxious weed Infestation
- Logging
- *Tillage*

Sometime in the last century soil erosion began to exceed new soil formation in large areas worldwide. In some parts of the world, farmland soils have been carried off by wind and water erosion at rates between 10 and 40 times the rates of soil formation. This has not been seen as a massive problem in the UK not least because we have been blessed with deep fertile soils. But soil erosion problems on farmland worldwide remain a fact and history is littered with examples of civilizations such as Norse Greenland and Minoan Crete whose collapse or serious decline, was triggered by an inability to maintain a fertile soil.

In recent history area such as the US Great Plains dustbowl in the 1930's, the Soviet Virgin lands in the 1960's and huge one forming today in the Loess plateau in North Western China have all had erosion problems, and we do have increasing evidence of this in the UK.

England and Wales loses 2.2 million tonnes of arable topsoil each year. Equivalent to a 1cm layer. 42% of UK land is now susceptible to erosion. Much of this contains pesticides and nutrients, if we can reduce the impact of wind and rain on the soil, which breaks it into crumbs then we can reduce the triggers of erosion.

A mulch preserving the soil structure, earthworms, organic matter and leaving surface residues to protect the soil surface and increase infiltration will reduce wind and water erosion more than any other crop production technique yet devised.

The organic surface cover stabilises the surface aggregates through reduced crust formation and surface sealing, resulting in less run off. It not only keeps soil particles in place but reduces herbicide and nutrient leaching. It can also reduce the costs needed to keep the watersheds clean from erosion.

If soil can be kept covered, erosion can be stopped before if starts. When a raindrop hits bare soil, it is like a small bomb and dislodges soil particles from the matrix. The first particles to be dislodged are the smallest colloids – these are the most fertile. Once dislodged they can easily be carried away.

Climate change predictions claim that future rainfall patterns will lead to more intense but shorter bursts of rainfall, rather than gentle drizzle. This will cause more soil erosion pressure if not adequately dealt with.

Furthermore earthworms (lumbricus terrestris) that create a permanent vertical burrow to a depth of more than 1 metre, are vital in preventing soil erosion by improving water absorption rates in soil. This is also more important as climate change patterns alter rainfall.

Soil Quality

The most important factor in determining soil quality is soil organic matter. The organic matter consists of living organisms, fresh and decomposing residue. Soil organic matter is made up of about 60% Carbon.

When the soil is opened up by tillage large amounts of Carbon Dioxide are released within a matter of days. This results in reduced organic matter and explains why it is very difficult to build up organic matter with tillage.

Whilst the plough releases the greatest CO^2 losses, lower losses have been recorded with minimum tillage.

A No Till system can build organic matter. And a No Till Green Manure system with a sound rotation can build a *lot* of organic matter.

Soil degradation affects 16% of EU land. Soil isn't soil without organic matter (OM) and in the UK some soils have worryingly low levels with an estimated 18% loss of OM between 1980-1995. In England and Wales a test on 6000 sites showed that there is 15% less Carbon in soils than 15 years ago. Much topsoil OM is likely to have stabilised in the past ten years, but this may not be agronomically and ecologically sustainable for good yields in the future. We may need to focus on rebuilding this.

There are also obligations on farmers to keep soil in **Good Agricultural and Environmental Condition** (**GAEC** – a cross compliance rule) and to do this they must satisfy three requirements:

- Maintain soil organic matter levels
- Reduce soil erosion
- Reduce damage to soil structure

The recently published Soil Atlas of Europe maintains that 75% of soils in Europe had OM content so low it is a cause for concern. Even with straw and crop residues OM can decline. Therefore we have a problem looming…

Soil Structure

A woodland or pasture has a natural structure. Different biological populations respire and operate at different depths and they all contribute to the soil as a living organism.

Providing the soil has not been too abused by traction in wet weather, agricultural grassland will be well covered, naturally friable and reasonably resilient to flood and drought. A soil with a poor structure will have fewer fissures, less oxygen and more waterlogging. No till tries to emulate the structure of a pasture or prairie.

Tillage over the years makes the soil unfit, and we spend time and energy knocking soil to create a tilth. Tillage destroys the structure of the soil leading to inevitable decline. Each time the soil is moved we destroy lots of mychorrizal and microbial interactions about which we are only starting to understand, but they do have a significant role in contributing to soil fertility.

A good surface mulch keeps the worms busy and fed, – a well structured soil has enormous resilience. The earthworm has excellent drainage abilities. Worm casts have more nutrients than the soil itself and are pH neutral.

Soil Fertility

The macro nutrients for plant production are Calcium, Phosphate, Potash and Nitrogen. There is a burgeoning interest in the idea that Carbon, in the form of organic matter, should also be considered a major nutrient.

Phosphate and Nitrogen are the predominant polluting nutrients often discovered in watercourses. A bare soil tends to lose the nutrients much more quickly and a healthy topsoil with a good surface mulch containing decaying, carbon-rich organic manure tends to keep nutrients in their place. Phosphate via reduced movement of soil colloids - which it clings to tightly, and Nitrogen via less leaching.

Historically such losses of fertility have been little recognised, they have even been regarded as a necessary by-product of high yield crop production. In the meantime some of our very best soils have degraded, but the loss has been hidden by the use of plentiful affordable artificial fertilisers.

A well mulched soil within a sound rotation allows a maximisation of soil fertility efficiencies. Phosphate is not known to leach from soil, it only moves with the soil, clinging tightly to the smallest colloids. Bare soil therefore exacerbates the problem; Phosphate tends to only get into lakes when placed there from soil erosion.

The aim therefore is to keep nutrients

a. in their place
b. recycling within the soil.

On a lot of the farms I visited Green manure covers were interspersed with the cash crops. In fact a lot of the farmers insisted that the seemingly nebulous idea of growing a crop merely to feed the soil was one of the key components to successful long term no tillage.

The Green manures perform various roles:

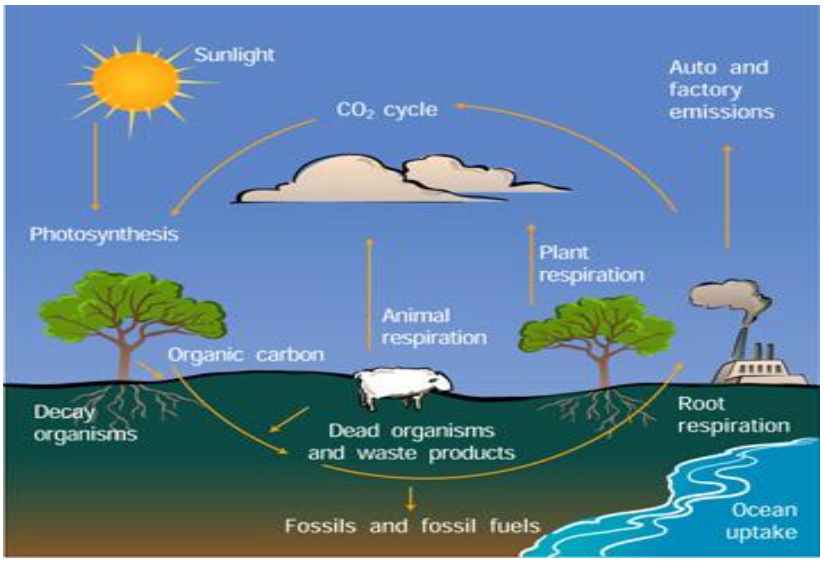
- Improve basic fertility of the soil
- Fix or lift nitrogen (and phosphorus)
- Weed suppression
- Pest Control
- Soil improvement

The green manure tended to be destroyed by Glyphosate, but mechanical methods could be used and frost could play a part on warm season crops. Many Paraguayan farmers would use a homemade knife roller to crimp the stems of a cover crop. They would wait until the cover crop reached full flowering – ideally 50-75% bloom, the plant would have then expended its energy but its seeds would still be green and not viable. The stems would then be laid flat onto the ground and would be biological soil *food.*

One comment I heard was that green manures "*appease natures desire for more biodiversity*" and correspondingly there was good evidence to demonstrate that those farming a varied cropping system were spending less money than those trying to maintain a monoculture. With green manure covers, more lucrative crops may be grown with substantially lower input costs.

Higher organic matter content can reduce the need for fertiliser by holding the nutrients in a non-leachable form, making fertilisers less polluting and more efficient.

Soil Carbon



The Carbon Cycle

During my Nuffield study the profile of the climate change debate has risen inexorably. Firmly in the centre of the political debate now, it seems that certain issues pertaining to climate change and how to progress within a low carbon economy will dominate our society in the future. Climate change and carbon emissions have become the zeitgeist, how does agricultural crop production contribute and how can it mitigate carbon and other greenhouse gas emissions?

Predictions of climate change in UK over the next 100 years are as follows:

- Warmer temperatures overall
- Milder, wetter winters
- Hotter drier summers
- More extreme weather incidents

There are two potential issues for agriculture here. One is being able to react to changes in a way that doesn't negatively affect their business and environmental obligations, and the other is to look at how farming practices can negate CO^2 emissions.

Scientists tell us, with 90% certainty, that the excess CO^2 entering the atmosphere is causing climate change. Science is making progress in reducing CO^2 emissions in the car, transport and energy industry but only agriculture and forestry can capture and reduce the CO^2 currently in the atmosphere. Agriculture therefore has a significant role to play. The importance of soil carbon sequestration has been hitherto largely ignored, not least because the Kyoto protocol has focused on trying to get countries to think more about reducing the demand/ supply side of fossil fuel use.

No tillage and mulches can allow the organic content of soil to increase at one tenth of one percent each year. Tilling in organic matter with the plough can waste as much carbon to the air as was intended to return to the soil. In a time when we are advocating biofuels to mitigate the factors contributing to climate change, is it not disingenuous not to look seriously at the carbon emitted from the soil in establishing them?

Carbon emissions from soils are notoriously hard to calculate but figures of 1.8 tonnes of CO2 per annum could be extracted from the atmosphere and returned to each acre of soil as organic matter, 1/10 of 1% of organic matter back in the soil where it is critically needed. As a comparator in the USA this would translate to taking out 540 million tonnes of CO2 from the atmosphere each year and returning it to the soil as organic matter where it is needed. It is oxidation of organic matter from tillage, rather than the amount of organic matter added which puts a limit on the long term health of the soil.

We currently emit 8 billions tonnes of CO2 per annum. Worldwide no till could make a significant impact on carbon sequestration.

Whenever there is a cover of mulch on the soil such as leaves, grass, manure, litter, compost, dead insects or any life form, there is decay going on at soil level. The decay rate is greatest when the temperature and moisture is best for plant growth. This decay is creating and releasing carbon dioxide into the atmosphere. Carbon dioxide is slightly heavier than air and it tends to stay trapped in the canopy of growing plants and grass. These plants now have an abundance of carbon dioxide to process into energy.

In a no till operation with annual crops, the soil is disturbed very little. Earthworms and many other forms of macro soil life are not disturbed or destroyed. Micro soil life, along with the miles of ultra fine plant root hairs are not disturbed or exposed to damaging sun rays and oxidation, which can quickly destroy them. So all the time, the mulch, is helping build the fertile soil.

In a natural environment the soil with its massive amount of Carbon based roots and other soil life is rarely exposed and destroyed.

Sustainable Agriculture

The malleable concept of sustainability leaps throughout today's political landscape, I still don't know what it really means, and everyone has their own interpretation. The only way I felt I could properly get to grips with the political idea of sustainability, or more accurately *Sustainable Agriculture* was not to look at existing systems of crop production and think "how can I make this more green?" But to take a holistic look, and see how I could design my farming system to provide maximum environmental health and economic profitability.

For example what system of crop growing would be the most fossil fuel efficient, and the cheapest? What would be the most ecologically benign for wildlife for watercourses? How can I save on soil erosion and make the best use of agro-ecological principles for nutrient, weed and disease management?

Sustainable Agriculture for me, starts with the soil by seeking to reduce (or eliminate) erosion, make improvements to soil physical structure, organic matter content, improve its capacity to hold water or allow water to better percolate or allowing plants to access water when they need to use it.

Soil health is improved through the use of legumes, green manures and cover crops; the incorporation of plants which have a capacity to fix N and reduce P losses from the soil.

The extraordinary growth in No Tillage in the Americas, whereby a permanent organic cover over the soil provides a function of physically protecting the soil from the weather and feeds soil biota. The result is reduced soil erosion, improved OM and carbon content. Zero tillage systems using green manures and cover crops for mulches contribute to humus in the soil. The system also requires less fossil fuel for machinery passes.

But for real carbon gains to be made, carbon sinks must become permanent. These systems not only accumulate carbon but are capable of delivering other public goods such as improved biodiversity and clean water from watersheds. This can make farming systems more energy efficient and save energy elsewhere.

The South Americans in employing tillage were faced with serious soil deterioration and as a result needed to find a different way to produce. Applying no till with a holistic approach enabled them to discover an entirely new scenery, a system based on understanding and emulating nature as much as possible.

Beyond the importance of soil sustainability, agriculture should be aim to provide greater diversity and therefore a greater agro ecosystem, leading to more beneficial organisms, fewer pests and diseases, more sustained crop yields and more opportunity for farmer innovation.

It is one way of turning agriculture from an EXTRACTIVE to a more RENEWABLE industry.

PART B

Machinery

In No Till systems there are two immensely important bits of equipment – the drill and the sprayer. It is vital these are properly functioning for success.

Western hemisphere farmers tend to spend a fraction of what European farmers invest in machinery. Depreciation costs are a major difference.

The benefits of no till are much greater for the user than the manufacturer. The manufacturer will sell a lot less steel and tractor horsepower when a farmer adapts to no till. As a consequence many drill manufacturers tend to focus exclusively on drills and do not have huge marketing budgets.

The design of the drills is not complicated, and in areas of South America many manufacturers seem to make exactly the same design of drill though the colour is different!

The most effective drill to use is a disc drill, such as the ones below:

This drill has double disc coulters which open a vertical slot in the soil, the seed is dropped between the opposing discs via a tube and then soil is pressed on top of the seed.

This drill only uses a single disc to open a vertical slot and a small seed boot runs in the ground dropping in the seed. Again a press wheel closes the opened slot. This is running wheat into a mustard cover crop on my own farm.

Tined drills do have a place in direct drill systems especially in Australia and Canada but in my view they are not adopting the agro-ecological potential of the mulch based system effectively enough. Tines cannot handle high residue very well and also tend to disturb more soil and therefore create more weeds. In my view their application is limited.

Poor machinery choice and a poor understanding of its operation is one of the main reasons for no till establishment failure. Though many farmers on my travels told me "*its not about the drill its about the system."*

Rotation

A sound rotation is incredibly important in mulch based systems. As a rule of thumb most practitioners would advocate at least three different crop types occupying no more than 33% of the rotation each. A sound rotation can help with many drawbacks such as perennial weeds, plant diseases, slow early season growth and compaction.

Examples of such rotation could be:

Brassica	**Grass**	**Legume**
	Wheat/ Maize	Beans
Oilseed	Wheat	Peas
Turnip	Grass/Oats	Soya

Interspersed where they can be with green manures for humus building. The more diverse a system the better it works. Different plants have different qualities, for example some legumes have a good ability to uptake and extract Phosphate as well as fix Nitrogen. Cereals are better than legumes at adding soil carbon content and the roots of brassicas can introduce oxygen. The rotation table should not be taken as a rigid rule however as each farmer needs to make his own economic decisions.

Ideally cash crops should be seeded at different seasons in the year. If a crop is established annually at the same time every year it can lead to specific weed problems which are hard to control. Planning and management is vital.

Pests, Diseases and Weeds

None of the farmers alluded to pests and diseases being major drawbacks to the system. They all had pest and disease problems of course, but they felt that they were developing the right strategies to deal with them. The more enlightened farmers didn't seek the answers for pest and disease problems from the chemical can as much as looking for biological solutions, such as cover crops, companion and nurse crops, seeding dates and reducing monoculture concentrations.

For example a few farmers claimed that with a mulch underneath the crop, the fungal pressure was reduced possibly as a result of less impact of rain on bare soil.

Chief amongst keeping on top of pest and disease pressure was using a solid rotation. Nature craves diversity, and a crop rotation provides the spatial diversity nature thrives on in a chronological form

Inputs

Most farmers operating mulch systems had a lot of proof of reduced inputs, but generally not at the expense of yield. No till drills do not require an immense amount of horsepower and correspondingly tractors were small and cheaper to run. For example a 3-4m drill can be pulled with under 100hp and would be capable of 50-80 acres per day. Therefore hp invested per hectare is low. They also spent less time driving their tractors with a one pass system so they clocked up fewer hours, and as a result needed to replace the tractors less frequently. Diesel costs were obviously lower too.

These farmers also tended to spend less on fertilisers and as long as a good mulch and low soil disturbance was maintained less on pesticides as well. This is because soil fertility builds up gradually and external fertiliser inputs should reduce. Initially nitrogen can be short before the biological cycling process improves. In general soil indices were much slower to reduce in the no till system. Once I heard a farmer say to me "*I'll never even do light tillage as I'll lose all my phosphate*." What he meant was that tillage exposes soil colloids and therefore phosphate to erosion and also indicated that the underlying biological activity contributing to phosphate cycling would be destroyed.

Chemical spend can increase in no till. Mulch cover is important in reducing these costs. A sound rotation is at the heart of reducing herbicide resistance and keeping inputs low – without the mulch and a rotation, no till becomes a more expensive and less sustainable action.

Economics

Economic Information can be hard to compare. In most cases yields from no till were as good or better than before although there were incidents where yields were less. A lot of farmers felt it was an adequate price to pay for cheaper costs.

One also needs to factor in the time element. No till establishment takes about 1/3 of the time of conventional.

The South Americans generally have the lowest costs in the world, and are generally the most profitable no till producers. Thanks in part due to the ability of soybeans to yield a good gross margin *and* fix nitrogen. Western Europe consistently struggles to find a break crop to match winter wheat. Low labour costs help as well but crucially South American producers have never been in a position to overcapitalise their farm businesses via subsidy – they are therefore extremely efficient with fixed costs.

Western European farmers will spend about $600 ha. on crop growing and Western hemisphere about $100 ha.. High yields do compensate but the relative difference remains substantial.

I further analysis of costs would be very valuable – it was noted that not many of the farmers wanted to go back to tillage systems having committed to no till.

Drawbacks

Most of the drawbacks of no till were seen as not enough of a problem for the farmers to feel they needed to return to the higher costs of a tillage system.

For example they felt management of rotation best conquered weed, pest and disease control. No till soils are often slower to warm up in the spring and are a bit wetter but these are not viewed as particularly problematic as long as the seed is capable of being planted and it is not sitting in excess moisture.

There are many people who feel continuous no till will not work because of compaction. Whilst there can be no set of guidelines for any soil type, many of the long term no tillers were convinced issues of compaction could be managed by soil cover, low ground pressure and lighter machinery.

The pest situation can change with no till however. Whilst slugs did not seem to be the biggest problem in the western hemisphere, the numbers of snails were increasing in no till fields. The management system tended to still remain consistent – rotate to stop the system becoming too predictable and allow the pest numbers to build.

One potential drawback of the system is that emissions of the greenhouse gas Nitrous Oxide have been recorded as higher in No Till systems. This gas is many times more potent than Carbon dioxide - possibly outweighing the benefit of CO2 sequestration from no tillage. More research is needed on this though but equally there is no reason why the problem could not be better managed in the future with different types of nitrogen sources. The problem is becoming more acute as focus of climate change develops. Recently some new information has been published that indicates that N^2O may possibly diminish quite rapidly after the initial changeover years.

Nitrous Oxide is an extremely difficult gas to measure – it would easily take up a Nuffield study on its own. It can vary from day to day, metre to metre and depends hugely on soil biota, climate, soil type etc. Furthermore if N doesn't leave the soil as a gas it could just as likely leave the soil as nitrate via leaching. The source of the N doesn't necessarily matter, suffice to say this is a new area that needs to be pursued with caution before drawing any conclusions.

CASE STUDIES

INNOVATOR #1

Steve Groff, Cedar Meadow Farm, Pennsylvania

Steve's definition of sustainable agriculture is to integrate no till practices and mulch cover crops to build soil quality and manage pests. "*Soil is meant to be covered*" is one of his favourite phrases to the degree that he wears a baseball cap to work displaying the quote!

Since the 1980's he has been practising what he preaches, to add fertility, protect and improve the soil, reduce chemical use and enhance water quality. The stability of the soils in his fields has improved and it has also helped his profits.

Groff is not limited to growing grain crops. No till tomatoes, pumpkins and sweetcorn are grown on the farm as well. This demonstrates that further developments in growing vegetable crops no till are a distinct possibility.

Groff is currently exploring the use of cover crops in between cash crops as subsoil conditioners to build soil biology, and reduce reliance on mechanical options.

"If the machinery that exists today had been around 150 years ago John Deere would have had no need to invent the self scouring steel mouldboard plough" Groff told me.

Whilst not a lone voice in his state, not everyone has followed his examples *"This has not taken off totally because society thinks we can still afford soil loss, organic matter depletion and heavy pesticide use as a price to pay for top yields, other places such as Brazil and Chile cannot"* said Steve.

I did witness that the tide is changing in Pennsylvania though. It now has a State funded No Till Alliance, when I arrived it had been established for just two months. Its aim was to encourage interest in No till and influence farmers to adopt the practice. The key driver for the state is that it needs to reduce Phosphate and Nitrogen leaching into the Chesapeake Bay area. The state university, conservation services and the National department of Agriculture were all involved. The advantage for the farmers

was that it would not just be environmental but economic too. It was also recognised that the organisation must be farmer driven and controlled for the maximum impact and credibility.

This photo is of forage radish that has been direct drilled into harvested sweetcorn. This will be left over the winter to scavenge nutrients and protect the soil. In the spring this will be sprayed off with glyphosate and a cereal crop will be established in one pass with a direct drill.

Pennsylvania's climate and topography are drivers for the adoption of no till. Intensive rains between July and September mean erosion is a problem, sloping land and thin stony soils exacerbate this. Many farmers who had adopted no till were delighted that it meant and end to stone picking that tillage machines used to bring to the surface!

INNOVATOR #2

Jeff Moyer, Rodale Institute, Pennsylvania

Jeff Moyer runs an organic research farm for the Rodale Institute in Pennsylvania. They are undertaking a project whereby they are trying to match the environmental benefits of organic farming with the conservation benefits of no tillage, which Jeff described as the "*best possible farming system for temperate climes*." This is it hoped will allow them to develop a pesticide free and carbon efficient crop production system.

To do this they used the cover crop roller in this picture to roll down a specially sown cover crop at flowering which achieves a 90%+ kill. It is a mechanical way of killing a crop rather than using herbicides. The subsequent cash crop is then direct seeded into the mulch.

The mulch performs a multifunctional role. The layer protects the soil from erosion, and prevents weed ingress by providing soil cover. It releases nutrients to the growing plant as the mulch decays and feeds the soil biota.

The crops that have been trialled so far are maize into a vetch cover crop and soybeans into ryegrass. The cover crop will be established in the autumn with the plough, this is then rolled in late April at flowering and the cash crop direct seeded into this.

The organic no till system has been trialled in various states of the USA and success rates have been varied not least because timing the rolling of the crop is crucial – it must be done when the cover crop has flowered so that it does not have enough energy to regrow. Choice of cover crop is important too.

Whilst the organic no till system clearly needs more development, it is a demonstration of the power the mulch can pay in suppressing weeds effectively. At Rodale they still rely on deep ploughing every year but there is no reason why no till technology could not be extended in organic systems to reduce the incidence of

ploughing or using covers and low disturbance principles in order to reduce external input use in conventional systems.

Jeff Moyer points out how effective weed suppression can be in this crop of organic forage maize (above). The ryegrass cover crop destroyed 6 months ago is still providing effective mulch.

"*No tillage without the green manure cover crop will only conserve what you have already got*" said Jeff, he wants to actively build soils as well as farm them.

INNOVATOR #3

Dwayne Beck, Dakota Lakes Research farm, South Dakota

The first thing Dwayne Beck said to me was there was "*no such thing as can't with no till.*" Beck runs a research farm just outside Pierre, the capital of South Dakota on the Northern Great Plains. A decade ago a group of farmers got together and asked Beck to form the research farm when they found that the State University wasn't providing them with the agricultural innovation they needed.

The traditional farming method in South Dakota had been summer fallow i.e. Winter Wheat established with two to three machinery passes followed by a years break. Wind erosion has been a major problem in the area. Whilst many farmers have been slow to change, those who have adapted to no till and attempted to get to a three year crop rotation, have started to reap the financial rewards and produce from land that had previously lain fallow for alternate years. The reason for this success is best highlighted by Beck's question "*Why is McDonalds open for breakfast*?" – The answer? Well it isn't because it makes much of a profit at breakfast time but it is more efficient to keep the system running than to shut it down. The same with the farm and the soil.

"You see, many methods we use are not solving the problems but dealing with the symptoms – such as buffer strips for erosion" said Beck. Dwayne Beck was designing a no till system to be efficient and holistic. Always good for a memorable comment he told me *"weeds and diseases are mother natures response to a lack of diversity in a cropping system.*"

Beck credits the high levels of active organic matter in virgin prairie soils for the astounding yields that the sodbusters of previous generations enjoyed. The only way to rebuild those soils, he says, is to continuously no till a varied rotation of crops to best manage residue.

"The real reason we do no till is because of profitability. All those other things are nice, and we like that. But you can't expect a farmer to do a system that isn't profitable because its better for bugs in the soil."

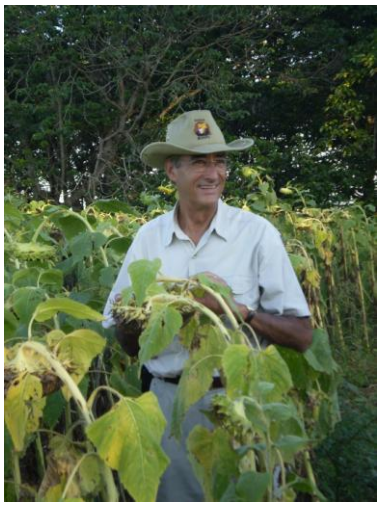
For South Dakota that means cover crops after wheat harvest, winter cover crops between corn and beans, and rotations that factor in grass and broadleaf plants as well as warm season and cool season crops. Taken together with intensive rotation, no till

becomes a comprehensive program - without the need to fall back on occasional tillage.

Dwayne Beck is very committed to putting some science behind a lot of his no till practices. He has data to prove that on his farm no till with a sound rotation reduces weeds. He encourages farmers to think biological time rather than of seasons. *"The more active your biological system is at the time means that the more pests and diseases will come and go – faster."*

Most of the Winter wheat under the South Dakota no till systems now requires very little herbicide in crop. Thanks to minimum soil disturbance, few weeds get the trigger to germinate. This generates big savings on what was previously the only profitable crop in South Dakota, and has introduced new ones that are capable of also turning in a profit.

INNOVATOR #4



Rolf Derpsch, Asuncion, Paraguay

Rolf Derpsch has been a pioneering promoter of no till in Latin America. Rolf has worked with farmers in Paraguay for the past 20 years promoting no till initially as a means of preserving soils from extreme erosion problems. Paraguay now had the greatest density of no tillage in the world, some 95% of its crops are grown under continuous no tillage. Rolf told me that no till is a "*total change of values on how to plant crops and manage soils. On adapting a higher level of management and becoming environmentally more responsible."*

Rolf very kindly showed me around some of Paraguay's most fertile areas and the relative prosperity of farmers adopting to no tillage was obvious to see. This included peasant farmers with 20 hectares or so, serving local markets, as well as large scale growers serving the international markets.

It was explained that 20 years ago soil erosion was a massive problem mainly due to the soil tillage and the subsequent intense tropical rainstorms that sent much of the soil onto roads and into watercourses. Once farmers started adopting no till and cover cropping they always tried to ensure there was something growing at all times to soak up the excess moisture and keep the soil well structured.

In the photo above Rolf is in a field of sun hemp. This was grown as a nitrogen fixing cover crop and will then be rolled to terminate growth. A cash crop will then be established. The soil will remain well structured, fertile and protected from soil erosion as the cash crop grows. Further herbicide will not be necessary thanks to the weed suppressing mulch. The establishment costs for this would be extremely cheap – one pass with a crimper roller and one with the drill. Diesel usage and tractor horsepower would be minimal. Surely one of the cheapest establishment systems in the world? And with some free nitrogen! Soil should always have a living root system in it, Rolf claims, without this nutrients will be wasted.

The Paraguayan farmers attach great importance to regular no till field days as a way of continually updating their learning. They all view no till as a systemic process and therefore never feel they have learned all about the process. No till Research and extension groups link at regional and national levels. These groups have been vital to the spread of no till farming.

At one meeting Rolf and I were guests of honour (Ok Rolf was!). In his speech after the traditional asado (barbeque), Rolf mentioned that he felt that whilst farmers had made much progress in developing no till systems they needed to push the system still further by looking at the latest developments in using green manures and adopting longer, more enlightened rotations to provide still greater efficiencies from their external inputs. He felt that the power of soil biology had been neglected over the past 50 years, at the cost of relying on chemistry instead.

The cusp of new no till research is likely to continue along the lines of using more effective covers for soil nutrition, and also looking at plants which display allelopathic and competitive effects to reduce weed germination, and looking at the interaction between soil microbes and crop disease.

A home made crimper (knife) roller for destroying cover crops without herbicide.

INNOVATOR #5

Carlos Crovetto, Chequen Farm, Concepcion, Chile

Carlos Crovetto has long been something of a long voice in his native Chile. Over the "hill" in Argentina he is much respected as one of the leading innovators in no till cover cropping systems in South America. He is probably one of the most perceptive writers on no tillage and soils in the world. He grows cereals and legumes on slopes up to $40^{0.}$

Crovetto says "*a no tilled soil with no residue (due to burning or removal) will never provide success and will be permanently dependent on agrochemicals*." In other words giving up tillage is not enough to conserve and produce better soils. He is pictured here in a cover crop of grasses, which are being topped to mulch the soil for a cash crop. There is no reason why ruminants could not have lightly grazed this crop however.

Listening to Crovetto is inspirational when he discusses the continuous improvement of his soils fertility thanks to no tillage and feeding the soil biologically. For example in the past 20 years he has increased his soils organic matter, massively reducing or eliminating his need for imported phosphates – he claims the phenomenal earthworm activity mineralises much previously unavailable phosphate. His soils have become more pH neutral minimising the need for imported calcium as well.

In the early 1980's Crovetto travelled to the UK and USA to look at emerging direct drilling scene in these countries. He bought a direct drill in each country and started experimenting. His intense and thoughtful observations have taught him much about soil interaction, which the science of the time had no explanation for. He emphasised however that mulch based agriculture is a system and it failed in the past because farmers neglected the systemic approach, for example the importance of rotational diversity and green manure covers.

Crovetto's rotation is generally Maize-Soya-Wheat-Lupins. Lupins do not pay him financially but have other benefits such as the deep taproot adds to the soil structure and the soil boosts yields within the rotation.

Crovetto really is ahead of his time. In fact his book on No Till is a very special one. It is an almost unique synthesis of looking at crop production and soil management in a way that surely hasn't been done before. Crovetto is equally comfortable looking at different soil indicators, therefore besides looking at soil chemical properties from the point of view of classic soil science he will also discuss soil biota and their role in helping soil fertility.

His book is brilliant but it may make your head hurt when you start reading it, such is its breadth and depth!

Barley grown on one of Crovetto's steep slopes

Conclusion

What I was lucky enough to do on my 8 week trip to the Western hemisphere was to have the time to develop a clarity of thought, thanks to a consistent message from a range of successful farmers and researchers. These farmers were working in quite different environments and on different soil types.

All reported genuine progress thanks to adopting mulch based agriculture and no tillage. It was enabling them to fulfil many of the tenets of what we require from sustainable agriculture. Each no till farmer tended to have a holistic viewpoint. One of them said to me "*the decompaction zone is in the mind not the soil*". Every farmer had a willingness to discuss nature and ecology as if it were the guide to helping them understand their farming system. A number of them had Fukuoka's book "The One Straw Revolution" on their bookshelves!

A no tilled soil is a fitter, healthier soil because of less human interference. The average farmer does not understand the importance of not tilling the soil, at a structural or microbiological level – it is an emerging science. In the meantime they could still enjoy its economic benefits and perhaps eventually other intangible benefits – better timeliness, less work and less stress.

Sometimes mulch based agriculture is confused by sceptics as an ideology or some sort of religion. The people I met argue that it is nothing of the sort, but it is a consequence of an economic and ecological thought process. No form of agriculture will ever be natural but the nearest thing to nature in terms of grain production is no tillage, which mimics the annual cycle of the meadow, prairie or forest. Originally designed for soil conservation it has now evolved into a financially rewarding and sustainable production system.

The challenge for the future is to maximise our agricultural output and at the same time minimise the effort and energy expended. Mulch based no till can allow us to do this, and it deserves farmer's attention and public support.

Recommendations

It is easy to make the enthusiasts mistake of advocating one system for all applications. Nevertheless my trip to the Western hemisphere and the information gleaned from some of the most experienced long term no till farmers actually reinforced a gut feeling that a crop growing system mimicking the cycle of nature would be profitable and more sustainable. It is not a panacea, but it just seems closer to a panacea than many things.

On my trip I felt I saw the proof. Hundreds of thousands of acres of it. In the wet, acidic, cold and stony soils of Pennsylvania. In the extremely dry and wind erosive soils of South Dakota. In the massively fertile and deep tropical soils of Paraguay. And in the steep, thin soils of maritime Chile. I felt I had seen enough variety to suggest that the system was transferable to the UK and Western Europe.

My view is that we need to make this technology work. In fact one of the initial adopters of mulch systems in South America once said "*I would not accept it will not work - we adapted to make it work*". This adaptation process included researchers, government departments and machinery manufacturers as well as the farmers.

The evidence is overwhelming that mulch based agriculture can contribute the public goods that will be demanded of farmers in the future. It can also contribute to their profitability once the intellectual cautiousness and the torpor induced by the current subsidy system is eliminated.

Lots of research has been done abroad and in many cases there is no need to reinvent the wheel. The principles will apply to the UK as much as the USA. Rotations will be different and certain technical differences will arise but the core practices are transferable to almost everywhere.

My recommendations could extend to a long list suggesting research from government bodies and assistance from extension agencies. Whilst such help is most welcome I also realise that the UK doesn't have a great system for "bottom up" adoption of research ideas in agriculture, besides there is nothing more useful than getting out there and physically doing. So my concluding recommendation is to farmers only – they are the ones who really matter:

If your interested in such a production system. Befriend one of the handful of people in the UK who are giving it a go. Learn the fundamental rules for success such as rotation, minimum soil movement and soil cover. And then go for it. It will work. And then tell you neighbours!

Your worms, watercourses and wallets will love you for it!

Postscript

This Nuffield Scholarship gave the immense privilege of galvanising me into approaching some people about whom I had read about and admired for some time. One often reads about the need to be open minded, but on occasions the people I met on my trip seemed to spark off innovative ideas that were thrilling in their approach. I concluded my Nuffield scholarship feeling invigorated and that I had started to study something very important for the future of crop production, and possibly sustainable agriculture itself.

On a personal level I am trying to practice what I have learnt and also to encourage others to give it a go too. I have bought myself a no till drill - on a 320 acre farm trying to farm without the single farm payment, funds did not stretch very far and so in fitting with what I learnt abroad I'm trying to farm economically. The drill was a 10 year old American import that had been sitting in the back of a farmers shed for 5 years. It was in better condition than much of the equipment I saw on my travels though.

First attempts proved that the system works. The future will involve further experimentation. I aim to try and incorporate more cover crops in the rotation and try to get them feeding the soil biology in an effort to reduce external fertilisers, to monitor the wildlife interactions, reduce pesticide use and to improve yield.

The aim is to try and farm for nothing but not at the expense of yield - an impossible aim I realise but the more I can extract from my farm for nothing the better my carbon footprint, the lower my investment and ultimately, my viability.

I have also made the first furtive attempts into setting up a UK Conservation Agriculture Alliance. We have our first open day coming off soon and it looks like the event will be well supported. To me it is an indication of a long road to be travelled to articulate the potential of Conservation Agriculture, but one well worth taking!

8. Further Reading

This has in no way meant to have been a comprehensive study of mulch based agriculture The following is a selection of further reading if you are interested in learning more:

Books:

No Tillage Seeding in Conservation Agriculture	Baker et al. (FAO)
Plan B 2.0	Lester Brown
Hands on Agronomy	Neal Kinsey
Agri-Culture	Jules Pretty
The Natural Way of Farming	Masanobu Fukuoka
The One Straw Revolution	Masanobu Fukuoka
Organic Gardening - The Natural No Dig Way	Charles Dowding
Guns, Germs and Steel	Jared Diamond
Collapse	Jared Diamond
No tillage	Carlos Crovetto

Internet References:

Direct Drilling Forum	www.farmingforum.co.uk/forum/
Steve Groff	www.cedarmeadowfarm.com
Dwayne Beck	www.dakotalakes.com
Organic No till	www.newfarm.org/depts/notill
Rolf Derpsch	www.rolf-derpsch.com/
UN Conservation Ag.	www.fao.org/ag/ca/